Protection of Ground Water Through Urban, Agricultural and Environmental Planning

How do public officials determine priority use when allocating a limited water supply?

When making water allocation decisions public officials must consider the impact on public need and welfare, the impact on natural waters and ecological systems, the impact on the local economy, and water resource sustainability. Existing uses are typically given precedence over new uses and in many cases a new use must demonstrate that it does not infringe upon an existing use. The following priorities should guide allocation decisions among competing uses and users:

Waters for human consumption, sanitation and safety

Waters for irrigation and livestock production (agriculture)

Waters for manufacturing or other industrial processes

Waters supporting aquatic ecosystems and threatened, endangered or protected species

Waters for generation of electrical power for public consumption

Waters for geothermal heating and cooling

Waters for recreational or aesthetic purposes

In areas with water limitations, water conservation is a method of extending water to more users and maximizes the benefits to the whole community. Partnering among various stakeholders for education programs that promote sustainability from water conservation-energy reduction-money saving efforts may be a good way to promote water conservation statewide. Locally, such efforts may also add to the economic success of the community in areas with water limitations. In the long run, educating the public on the energy and cost savings of water conservation is probably the most powerful stimuli towards long-term water conservation.

Should urban uses have priority over agriculture?

In most cases, human needs are given first priority and agriculture is second. However, agriculture is a necessary human need providing food. Residential water use can make up a substantial percentage of the total water use. A significant portion of this water use is non-consumptive use such as irrigation of turf grass and landscape. Thus, if urban communities were to become better stewards of their water resources, they must develop best management practices (BMPs) for all aspects of water utilization. Research and educational programs will need to be developed that focus on all areas of water usage, including programs aimed at improving irrigation efficiency in urban agriculture.

Should agriculture have a higher priority which may preclude or limit urban growth?

There needs to be a balance between urban growth and the agriculture that ultimately sustains it. Growth and development will continue to be dictated to a large extent by the availability of adequate water supplies. As such, increasing pressure is being placed on water users, both small and large, to become more efficient in all aspects of water utilization. Local and state water agencies will therefore need to investigate all possible water management strategies that will enable the wise and efficient usage of the available water resources. Water management strategies need to be developed not only for conventional agriculture but also for urban water utilization.

What about environmental uses such as maintaining instream flows, aquatic life and habitat?

Instream flow regimes that have natural variability of quantity, timing, and quality are required to sustain healthy freshwater ecosystems. Assessments resulting in ecologically relevant flow metrics describing variability which includes magnitude, frequency, duration, timing, and rate of change flow events is needed.

What is the role of storm water management?

The role of storm water management is to describe the procedures and practices an agency uses to reduce the discharge of pollutants from storm drainage systems.

What is the link between threats to both surface water and ground water quality/quantity?

Threats to both surface and ground water may be either manmade or naturally occurring, although since the two are inseparably linked, a problem with one will inevitably mean a problem with the other.

Groundwater Threats

Manmade

Many human activities can negatively affect groundwater quality as well as quantity. For many years it was generally believed that the filtering capabilities of the soil protected groundwater from contamination by human activities on the surface.

But with the discovery in the 1970s of manmade organic chemicals in groundwater, we began to realize how extensively our activities can affect groundwater. In fact, in a nationwide study commissioned by the U.S. Environmental Protection Agency, 65 percent of the private wells tested failed to meet at least one drinking water standard.

Those activities that can have a negative impact on groundwater can be categorized into four groups: waste disposal, resource extraction, agricultural practices, and urbanization.

Waste Disposal
The best known source of groundwater contamination is waste disposal sites (landfills), both municipal and industrial, that were in existence before new regulations went into effect in 1988.

Septic systems are another potential source of groundwater contamination. If septic systems are improperly installed or maintained, bacteria, viruses, nitrate, phosphorus, chlorides, and the organic solvents that are found in many household cleaners as well as products sold to "clean" septic systems can all make their way into groundwater. As a result of poor construction or maintenance of their septic systems, rural homeowners are frequently the cause of contamination of their own wells.

Resource Extraction
As mines intersect aquifers and collect water, they interfere with groundwater storage and can lead to lowered water levels in wells.

Drainage from mining degrades water quality as it infiltrates aquifers or discharges into streams. Increased concentrations of iron, manganese, sulfate, and dissolved solids in well water can result. Stone quarries can have a negative impact on both groundwater and surface water sources.

Agriculture
Common agricultural practices such as fertilizing and applying pesticides are coming under increased scrutiny because groundwater samples have revealed nitrates and, in some cases, pesticides. The most prevalent problem is high levels of nitrate from overapplication of manure and fertilizer. Nitrate is especially harmful to babies, interfering with the blood's ability to transport oxygen, which causes the baby to suffocate ("blue baby" disease).

Urbanization
Many human activities and land use practices, which proliferate with urbanization, can negatively affect groundwater. Even cemeteries, for example, can contaminate groundwater.

One effect of urbanization is recharge diversion. Soils that have been covered with impervious surfaces-roofs, parking lots, or streets-obviously cannot absorb precipitation. Nor can soils that have been compacted by heavy machinery. As a result, much of the water from rain and snowmelt goes directly into streams and is never available to recharge groundwater.

Large concentrations of people can also lead to overpumping of aquifers. This can result in significant aquifer draw down, which in turn reduces the quantity of streamflow. Stream water quality then suffers due to higher concentrations of sewage treatment plant effluent. Intensive pumping in coastal areas can cause salt water to be drawn into aquifers and wells. Polluted stream water can also be drawn into drinking water wells.

With increased population comes industrialization and an increase in the amount and variety of industrial activities, many of which can potentially contaminate groundwater. Leaking storage tanks at both industrial sites and gas stations have contaminated groundwater in many instances.

Surface Water Threats

Because surface water (rivers, streams, ponds, lakes, reservoirs, and springs) are by their nature more "visible," most people have more experience with this water source. Surface waters are often areas of recreation that provide us with opportunities for swimming, boating, fishing, and camping. Most of us have pleasant memories and experiences related to these water habitats and view them as a wonder of nature, representing crisp, clear, clean water.

While many of the threats talked about in the Groundwater Threats section relate to surface water sources, surface water is even more vulnerable to contamination because of its readily available nature. Surface waters can be contaminated by pollution from "nonpoint sources," sometimes called "polluted runoff," or "point sources," usually permitted discharges from sewage treatment or industrial waste treatment plants.

How can they best be addressed?

Federal regulations contained in the Clean Water Act and Safe Drinking Water Act play a key role in the protection of water supplies. Communities can use an array of different source water protection methods to prevent contamination of their water supplies:

- Some management options involve regulations and ordinances, such as prohibiting or restricting land uses that might release contaminants in critical source water areas.
- Education and outreach can also be effective. Many communities hold local events or distribute information to encourage citizens and businesses to protect drinking water sources by recycling used oil, limiting their use of pesticides or participating in watershed cleanup activities.
- Many of the available management measures are known as best management practices (BMPs). BMPs are standard operating procedures that can reduce the threats that activities at homes, businesses, farms, and industrial facilities can pose to water supplies.
- Purchasing land or creating of conservation easements can form a protection zone near the drinking water source.

Conserving the quantity of water is easy. By simply reducing the amount of water that we use in daily activities, fixing leaks, and irrigating wisely, our water supply will last longer. In agricultural areas, water may be saved by using more effective irrigation methods. In industrial areas, manufacturers can save water by reusing it and by treating industrial wastes. Cities and towns can save water by eliminating leaks and installing meters. Wastewater can be treated and reused.

Formation of water management districts, such as the Capital Area Ground Water Conservation Commission and Sparta Commission, promotes orderly development of ground water resources and protects the quality of these resources. The state Department of Natural Resources Office of Conservation can also designate “areas of ground water concern”, identifying areas experiencing excessive water level declines. The designation requires an aggressive water conservation education program, submittal of monthly water usage reports by non-domestic well owners, and the pursuance of alternative sources of potable water to reduce groundwater usage.

Who should have jurisdiction to oversee the protection and management of large ground water basins for both quality and quantity (e.g., recharge)?

In Louisiana the Department of Environmental Quality oversees the protection and management of large ground water basins from a quality standpoint while the Department of Natural Resources oversees it from a quantity standpoint. However, to be most effective, water protection and management should be integrated, involving users, planners, and policy makers at all levels.

What are the consequences of poor planning, unreasonable decisions, and lack of effective actions?

Poor planning and decision making can ultimately lead to impaired surface water bodies, ground water contamination, and ground water overdraft, reducing the supply of clean water. As world population grows the competition for scarce water resources will increase in the future, as the demand for water from agriculture, industry and private households will rise. Inefficient use and water contamination will impoverish this and future generations, destroy the limited remaining aquatic ecosystems, threaten our future food supply, and have public health ramifications.

How can public officials address future threats to surface and ground water resources?

Effective water quality monitoring and protection will help protect public and environmental health. Future threats can be addressed through management options such as ordinances, which prohibit or restrict land uses that might release contaminants in critical source water areas. Well-designed and solidly resourced monitoring programs are absolutely essential to document trends in freshwater supply and use, to support research, and to measure and assess impacts of water policies and management and operational practices.

Water Quality and Quantity

Know the two greatest users of fresh water in Louisiana and in North America and explain why conjunctive use of groundwater and surface water is important to groundwater management and optimizing supply.

Louisiana

In 2005, approximately 10,300 Mgal/d (million gallons per day) of fresh water was withdrawn from groundwater and surface-water sources in Louisiana. Total groundwater withdrawals were about 1,600 Mgal/d, and total surface-water withdrawals were about 8,700 Mgal/d. From 2000 to 2005, groundwater withdrawals in Louisiana decreased by 3.7 percent, and surface-water withdrawals were unchanged. Total water withdrawals in Louisiana decreased by less than 1.0 percent from 2000 to 2005. Water withdrawal totals in Mgal/d in 2005 for various categories of use were as follows: power generation—5,200 (Louisiana's number one greatest fresh water user), industry—3,100 (Louisiana's number two greatest fresh water user), rice irrigation—790, public supply—720, aquaculture—270, general irrigation—200, rural domestic—44, and livestock—8.0. From 2000 to 2005, changes in withdrawals, in percent, for the categories of use were as follows: public supply decreased by 5.1, industry increased by 16, power generation decreased by 7.7, rural domestic increased by 6.0, livestock decreased by 58, rice irrigation decreased by 11, general irrigation increased by 52, and aquaculture increased by 11. Forty-two percent (about 660 Mgal/d) of all groundwater withdrawn was from the Chicot aquifer system, and 26 percent (about 400 Mgal/d) was withdrawn from the Mississippi River alluvial aquifer. Since 2000, withdrawals from the Chicot aquifer system decreased by 17 percent, and withdrawals from the Mississippi River alluvial aquifer increased by 14 percent. About 76 percent (6,700 Mgal/d) of all surface water withdrawn was from the Mississippi River mainstem. This value represents a 7.6 percent increase in withdrawals from 2000 to 2005.

United States

About 410,000 million gallons per day (Mgal/d) of water was withdrawn for use in the United States during 2005. About 80 percent of the total (328,000 Mgal/d) withdrawal was from surface water, and about 82 percent of the surface water withdrawn was freshwater. The remaining 20 percent (82,600 Mgal/d) was withdrawn from groundwater, of which about 96 percent was freshwater. If withdrawals for thermoelectric power in 2005 are excluded, withdrawals were 210,000 Mgal/d, of which 129,000 Mgal/d (62 percent) was supplied by surface water and 80,700 Mgal/d (38 percent) was supplied by groundwater.

Water withdrawals in four States— California, Texas, Idaho, and Florida— accounted for more than one-fourth of all fresh and saline water withdrawn in the United States in 2005. More than half (53 percent) of the total withdrawals of 45,700 Mgal/d in California were for irrigation, and 28 percent were for thermoelectric power. Most of the withdrawals in Texas (26,700 Mgal/d) were for thermoelectric power (43 percent) and irrigation (29 percent). Irrigation accounted for 85 percent of the 19,500 Mgal/d of water withdrawn in Idaho, and thermoelectric power accounted for 66 percent of the 18,300 Mgal/d withdrawn in Florida.

During 2005, about 44,200 Mgal/d of freshwater was withdrawn for **public supply**, which accounted for about 11 percent of the total water withdrawn. About 67 percent of the freshwater withdrawals were from surface-water sources. Public suppliers deliver water to users for domestic, industrial, commercial, and other purposes. **Domestic** use includes indoor and outdoor residential uses, such as drinking water, sanitation, and lawn watering. About 58 percent of public-supply withdrawals, or 25,600 Mgal/d, was for domestic use. Some residences, especially in rural areas, are not connected to public-supply systems, and water for domestic use is self-supplied from wells or other private sources. Self-supplied domestic withdrawals were 3,830 Mgal/d during 2005, which provided water for about 42.9 million people, or 14 percent of the U.S. population. Nearly all of the water withdrawals for self-supplied domestic use were from groundwater.

Withdrawals for **irrigation** totaled 128,000 Mgal/d, second only to total withdrawals for thermoelectric power, and represented 31 percent of total withdrawals and 37 percent of freshwater withdrawals. Irrigation includes water applied by irrigation systems used in agricultural and horticultural practices. Sprinkler systems were used on about half of the irrigated acreage nationwide in 2005, and surface water supplied about 58 percent of the total irrigation withdrawals. Of the total irrigation in the United States, 85 percent of the withdrawals and 74 percent of the acres irrigated were in 17 conterminous Western States.

Combined withdrawals for livestock and aquaculture were less than 3 percent of the total water withdrawals in 2005. **Livestock** withdrawals include water for livestock, feedlots, and dairy operations, and accounted for 2,140 Mgal/d, most of which (60 percent) was supplied by groundwater. **Aquaculture** includes fish farms and fish hatcheries and accounted for 8,780 Mgal/d of freshwater withdrawals, about 78 percent of which were supplied by surface water.

Self-supplied **industrial** withdrawals were an estimated 18,200 Mgal/d, about 4 percent of total withdrawals. Industrial water use includes water used in manufacturing and producing commodities, such as food, paper, chemicals, refined petroleum, wood products, and primary metals. Although some water for industrial uses was delivered by public suppliers, this amount was not estimated for 2005. Surface water was the source for 83 percent of self-supplied industrial withdrawals. Less than 7 percent of total industrial withdrawals were saline water, and 97 percent of the saline water used was surface water.

Mining water use includes water used for extracting solid minerals, such as copper; liquids, such as petroleum; and gases, such as natural gas. Withdrawals for mining were estimated to be 4,020 Mgal/d for 2005, or about 1 percent of total withdrawals. Groundwater supplied 63 percent of water withdrawn for mining purposes, and about 58 percent of mining withdrawals were freshwater.

Water for **thermoelectric power** is used in the process of generating electricity using steam-driven generators. Thermoelectric power accounted for 49 percent of total withdrawals, or 201,000 Mgal/d. Surface water was the source for 99 percent of thermoelectric-power withdrawals, and 28 percent of the surface water was saline. Thermoelectric power plants that use once-through cooling systems accounted for 92 percent of thermoelectric power withdrawals; recirculating cooling systems made up the remainder. Very large volumes of water are needed for cooling in thermoelectric power plants, which is why they generally are located near the coasts, the Great Lakes, and large rivers. Most (84 percent) of thermoelectric-power withdrawals in 2005 were in the Eastern States; many Western States rely on hydroelectric-power generation for much of their power needs. Hydroelectric power is an instream use and is not included in the 2005 estimates of water use. A bar graph of water withdrawals by major category and State, arranged from west to east, shows the general geographical pattern of water use. Irrigation dominated withdrawals in many Western States, especially those with only minor thermoelectric-power withdrawals. Generally, thermoelectric power was the largest category of water withdrawal in the Eastern States.

Total withdrawals for 2005 were less than 1 percent lower than the revised estimate of withdrawals for 2000 (413,000 Mgal/d). Water-withdrawal estimates made by the U.S. Geological Survey (USGS) at 5-year intervals since 1950 peaked in 1975 and 1980, when major categories of thermoelectric-power generation and irrigation were largest. Irrigation withdrawals generally have declined since 1980 even though the amount of irrigated acreage has increased. Conversely, thermoelectric power withdrawals declined sharply in 1985 but have been increasing since and regained the same level of withdrawal as in 1975 again in 2005. Withdrawals for public supply have increased steadily since 1950 along with the percentage of the population that is served by public-supply systems. Domestic withdrawals also have increased generally since 1950 as increases in per capita use balance or outweigh declines in the self-supplied population. Self-supplied industrial water use is the only category that has declined consistently since 1985 when the category was first compiled separately from the commercial, mining, and aquaculture categories. Industrial withdrawals in 2005 were almost 8 percent lower than in 2000.

Percentage Water Use By Category – United States
Thermoelectric power (49%)
Irrigation (31%)
Public supply (11%)
Industrial (4%)
Aquaculture (2%)
Domestic (1%)
Mining (1%)
Livestock (Less than 1%)

Percentage Water Use By Category – Canada
Thermoelectric power (60%)
Manufacturing (18.5%)
Public Supply (9.5%)
Agriculture (8%)
Mining (4%)

Percentage Water Use By Category – Mexico (surface water data only, similar groundwater data unavailable)
Agriculture (78%)
Domestic (17%)
Industry (5%)

Conjunctive use of surface and groundwater

Conjunctive use of surface and groundwater consists of harmoniously combining the use of both sources of water in order to minimize the undesirable physical, environmental and economical effects of using solely surface or groundwater and to optimize the water demand/supply balance. Usually conjunctive use of surface and groundwater is considered within a river basin management program - i.e. both the river and the aquifer belong to the same basin. The conjunctive use of surface and groundwater is one of the strategies of water supply management which has to be considered to optimize the water resources development, management and conservation within a basin.

The adoption of an integrated river basin management approach for elaborating policies and strategies of water resources development, management and conservation would help consider the water resources as one system and would avoid a water resources development approach focused only on surface water. This approach also facilitates the management of the resource itself, allowing a better understanding, by water users, of the hydrological issues involved.

Know the potential sources of pollution to groundwater in Louisiana and evaluate strategies for cleanup or improving groundwater quality.

Significant POTENTIAL Source Of Contamination (SPSOC or Potential Source) – Any facility, location, or activity that stores, uses, or produces as a product or by-product, contaminants of concern and has sufficient likelihood of releasing such contaminants at levels that could pose a concern relative to drinking water sources.

Contaminant – A substance detrimental to humans, animals, or plants. When found in water, contaminants are typically measured in parts per million (PPM) or parts per billion (PPB). The standards most commonly used for contaminants are set by the U.S. Environmental Protection Agency.

Significant POTENTIAL Sources Of Contamination Affecting Ground Water Drinking Water Sources

HIGHER RISK
Abandoned Water Well
Above Ground Storage Tank
Agriculture Chemical-Formulation/Distribution (pesticide/insecticide)
Animal Feed Lots/Dairies
Battery Recyclers
Body Shop/Paint Shop
Cercla Site
Chemical Plant
Class V Injection Wells
- Motor Vehicle Waste Disposal Wells
- Industrial Waste Disposal Wells
- Large Capacity Cesspools
Dry Cleaner/Laundromat
Inactive/Abandoned Site
Major Industrial Site Plume
Military Facility
Petroleum
Septic System
Truck terminal
Underground Storage Tank
Wood Preserving Plant

MEDIUM RISK
Airport
Auto/Boat/Tractor/Small Engine Shop
Class I Injection Well (Industrial & Hazardous)
Class II Injection Well (Oil & Gas)
Class III Injection Well (Mining Salt or Sulphur)
Furniture Stripping
Inactive Water Well
Oil/Gas Well & Associated Drilling Activities
Oil/Gas Tank Battery
Oxidation Pond
Promiscuous Dump
Railroad Yard - Switching
Railroad Yard- Loading and Offloading
Railroad Yard- Maintenance
Sand/Gravel Pit
Sanitary Landfill (active or inactive)
Sewer Treatment Plant (& impoundments)

LOWER RISK
Asphalt Plant
Car Wash
Cemetery
Funeral Home
Golf Course
Hospital
Irrigation Well
Lumber Mill
Metal Plating/Metal Working
Nuclear Plant
Paper Mill
Pipeline Compressor Stations
Plant Nursery
Port Facilities
Power Plant
Printing Shops
Salvage Yard
Sewer Lift Station

Line Potential Sources of Contamination
Railroads, Pipelines and Sewer Lines, Roads, and Hazardous Waste Transport Routes are Line Potential Sources of Contamination subject to spills and leaks. Septic systems reported as a density.

Strategies for Cleanup

Pump and treat is a common method for cleaning up groundwater. Pumps are used to bring polluted groundwater to the surface where it can be cleaned up (*treated*) more easily. To remove polluted water from underground, an *extraction system* is built. This system usually consists of one or more wells equipped with pumps. When the pumps are turned on, they pull the polluted groundwater into the wells and up to the surface. At the surface, the water goes into a holding tank and then on to a treatment system, where it is cleaned. There are a number of treatment methods which can be used which either to destroy the polluting chemicals or to remove them for proper disposal. The cleaned water can then be put back into the ground, into a public sewer, or into a pond.

Common Treatment Methods

Air stripping – This is a process of forcing air through polluted groundwater or surface water to remove harmful chemicals. The air causes the chemicals to change from a liquid to a gas (evaporate). The gas is then collected and cleaned. Air stripping is commonly used to treat groundwater as part of a pump and treat remedy.

Activated carbon – Material is used to filter harmful chemicals from polluted air and water. It looks like tiny granules of black sand. As polluted water or air flows through an activated carbon filter, chemicals *sorb* or stick to the surface and within the pores of the granules. Most tap water filters and fish tank filters at home contain activated carbon and work the same way. Activated carbon filters are often used as part of a pump and treat system to clean up polluted groundwater.

Bioremediation – This allows natural processes to clean up harmful chemicals in the environment. Microscopic “bugs” or *microbes* that live in soil and groundwater like to eat certain harmful chemicals, such as those found in gasoline and oil spills. When microbes completely digest these chemicals, they change them into water and harmless gases such as carbon dioxide.

Chemical oxidation – This process uses chemicals called *oxidants* to destroy pollution in soil and groundwater. Oxidants help change harmful chemicals into harmless ones, like water and carbon dioxide. Chemical oxidation can destroy many types of chemicals like fuels, solvents, and pesticides.

In order for pump and treat to be effective, the source of the pollution must first be taken away so that it will not continue to seep into the groundwater. For example, leaking oil drums or tanks must be removed and the surrounding polluted soil must be cleaned up.

Pump and treat is quite safe when designed and operated properly. Since the polluted groundwater is pumped directly into holding tanks and from there into the treatment system, no one comes in contact with any harmful chemicals. The harmful chemicals are destroyed or removed and disposed of properly. The cleaned water is tested to make sure it is safe before it is put back into the ground or into a sewer system. EPA tests the groundwater regularly during the pump and treat process to make sure all of it is being collected and it is not spreading further.

Cleaning up polluted water while it is still underground is often very difficult and sometimes not possible. Pump and treat is the best remedy in such cases. Pump and treat can also be used to help keep polluted groundwater from spreading into nearby drinking water wells while other kinds of cleanup actions are being taken.

Natural attenuation is another option which relies on natural processes to clean up or *attenuate* pollution in soil and groundwater. Natural attenuation occurs at most polluted sites. However, the right condition must exist underground to clean sites properly. If not, cleanup will not be quick enough or complete enough. Scientists *monitor* or test these conditions to make sure natural attenuation is working. This is called *monitored natural attenuation* or *MNA.*

Due to the complexity of aquifers and the types of contamination, not all groundwater can be restored to a safe drinking quality. In particular, contamination by common solvents and oily waste pose a common, major hurdle for groundwater cleanups. In such cases, current strategies rely on reducing and containing groundwater contamination.

Identify actions citizens can take to protect and conserve groundwater.

Actions to protect groundwater in the home

Dispose of wastes properly. Wastewater treatment plants are not designed to treat harmful chemicals such as paint, oil, solvents, and pesticides. Therefore, it is important not to dump these substances down the drain, toilet, or sewer. Landfills also can not handle these substances so do not put them in the trash. You can dispose of these substances at your local household hazardous materials collection day.

Limit use of hazardous products in the home. These products include oven cleaner, toilet bowl cleaner, bleaches, paints, furniture cleaner, carpet cleaner, and glue, among others. Share what you do not use with churches, schools, or neighbors instead of disposing of it. Use non-hazardous products when possible. You can find “environmentally friendly” products or make your own cleaning solutions. **Recipe for all-purpose cleaner:** 1 gallon hot water, 1/4 cup household ammonia, 1/4 cup vinegar, 1 tablespoon baking soda.

Use pesticides and fertilizers in moderation. Instead of using chemicals, consider pulling weeds or infected leaves by hand or using some type of biological control such as ladybugs.

Avoid spilling or pouring automotive wastes such as oil or gas on the ground during maintenance. After changing oil, dispose of it at a local oil recycling center.

Actions to protect groundwater in the business

Use chemicals as per directions and dispose of chemicals properly.

Use the least hazardous or least concentrated products available to accomplish their processes.

Do not dump solvents, used oil, or toxic chemicals down storm drains. Seal floor drains.

Do not dump waste that contains organic chemicals or metals into septic systems. These must be recycled.

Store chemicals in covered areas and in areas with paved or impervious surfaces.

Use secondary containment around containers to catch spills or leaks.

Make sure all chemicals and other materials are labeled and are stored in proper containers. Containers should not be corroded or leaking and should be sealed to prevent spills.

Monitor use of all raw materials and wastes. Purchase responsibly to decrease the amount of stored chemicals and waste.

Use measures to prevent overflow of tanks.

Place drip pans where chemicals are stored or where they might leak, for example, under machinery. Recycle or dispose of the substance properly.

If a liquid chemical spills, clean it up with a dry absorbent. Do not wash down drain.

Use spring loaded funnels or pumps to dispense and collect fluids such as antifreeze, solvents and used oil.

Use non-chlorinated compounds for parts cleaning.

Remove parts slowly from solvent to prevent spills.

Use a filter on parts cleaner to extend the life of the solvent.

Recycle as many substances as possible such as antifreeze, solvents, and used oil.

Keep hazardous and non-hazardous wastes separate.

Maintain an accurate inventory of materials and disposal records.

Have a spill control and response plan and keep it where it can be easily viewed by employees.

Actions to conserve groundwater

By making just a few small changes to your daily routine, you can save a significant amount of water, save money and preserve water supplies for future generations. Below are some suggestions.

Turn water off while brushing your teeth or shaving.

Turn off faucets completely.

Take a short shower instead of a bath.

Use faucets and shower heads that restrict water flow.

Place a one gallon plastic container full of water in the toilet tank. It will displace and therefore save up to a gallon of water.

Wash full loads when washing clothes.

Adjust the water level control on the washing machine appropriately.

Keep a bottle of water in the refrigerator for drinking. You will not have to run faucet water until it gets cold.

Use garbage disposal once instead of several times.

Wash full loads in the dishwasher.

Use small pans of water to wash vegetables rather than running water over them continuously.

Clean driveway and sidewalks with a broom and not a water hose.

Do not fertilize the lawn in the summer.

Park the car in the grass while washing it, therefore watering the lawn at the same time.

Water lawn and garden in early morning or at night.

Use drip irrigation.

Pull weeds that compete with plants for water.

Check all pipes and faucets for leaks.

Appraise the value of groundwater as a component to an integrated regional water management plan, and propose strategies to increase and replenish groundwater supplies.

In most climates of the world, precipitation, either rain or snow, and consequently peak runoff corresponding to a significant part of the total discharge of the rivers, occur during a particular season of the year which usually coincides with the smallest water demand. The water development problem therefore consists of transferring water from the high supply season to the high demand season. The most obvious and the most common solution to that problem consists of storing surface water behind dams. Yet surface reservoirs have many drawbacks, especially:

• **evaporation**: large open water areas are exposed, during several months and even years, to high evaporation rates leading to water losses sometimes exceeding 20 percent of the average annual runoff. Losses may be even higher when the width of the impounded valley is considerable, and induces a larger open water area.

• **sedimentation**: soil erosion in the catchment results in siltation in the surface reservoirs and in the equivalent reduction of the storage capacity.

• **environmental impact** of surface reservoirs may often be highly undesirable for human health, flooding of inhabited, or good agricultural land,

• **distribution of water** from the reservoir may be expensive and requires the construction of costly canals because of the distance between dam and utilization areas.

In contrast, groundwater is not exposed to evaporation, does not suffer from reduction of storage capacity because of siltation, is seldom harmful to environment and offers a natural water distribution up to the users.

Considerations to be studied when utilizing groundwater include:

• underground storage availability,

• production capacity of the aquifer(s) in term of potential discharge,

• natural recharge of the aquifer(s)

• induced natural recharge of the aquifer(s)

• potential for artificial recharge of the aquifer(s)

• comparative economic and environmental benefits derived from the various possible options.

Strategies to increase and replenish groundwater supplies should include a two-fold approach of water supply management and water demand management (conservation). Water supply management for groundwater includes both artificial and natural recharging of aquifers.

Should a significant natural recharge of the aquifer occur from the surface runoff and the deep percolation of rainfall, and should the average annual amount of recharge be of the same order of magnitude as the water demand, there would not be the need for any additional human intervention. On the contrary, any tentative modification of the natural course of surface water may significantly alter the groundwater renewable resources. There are many examples of double counting of water resources as if surface and groundwater were independent. Because of this wrong approach, dams have been built with the intent to store the surface water and to create an additional resource. The resulting situation has often been catastrophic with rapid depletion of the aquifer not recharged any more, destruction of the ecosystem based on the groundwater and extreme difficulty to go back to initial conditions.

Induced natural recharge occurs when intensive exploitation of groundwater close to a river results in an important depression of the groundwater level and in a water inflow from the river. This phenomenon is well known in temperate climate where rivers flow all year long; but it may also occur in semi-arid climates where a depression of the piezometric level of an aquifer underlying a temporary river creates the empty space in the aquifer which facilitates its recharge during floods.

Artificial recharge of aquifers can be achieved using three different methods, namely **surface spreading, watershed management** (water harvesting) and **recharge wells.**

Surface spreading

Artificial recharge by the spreading method consists of increasing the surface area of infiltration by releasing water from the source to the surface of a basin, pond, pit or channel (flooding). This is certainly the most efficient and most cost-effective method for aquifer recharge. However, only phreatic (unconfined) aquifers can be recharged by the spreading method, which also requires large surface areas to accommodate the recharge scheme, allowing water to evaporate if percolation in the ground is slow.

Surface spreading usually needs two structures: the diversion structure and the infiltration scheme.

Diversion structures are the same as those used for spate irrigation. The traditional methods, based on centuries of experience, are well adapted to the conditions of arid land. They consist of the construction of earthen bunds (*ogmas*) and deflectors to divert the flow into fields. But large spates usually destroy the *ogmas* and reduce irrigation of the fields. Furthermore, the very high sediment content of spate water tends to fill the diversion canals, which have to be cleaned regularly. So, although the ogmas are relatively inexpensive to rebuild, the overall cost of seasonal maintenance and repair of the scheme is high.

The **infiltration scheme** may consist of basins, channels or pits depending on the local topography and on land use. The most common system consists of a number of **basins** each one having an area ranging from 0.1 to 10 ha according to space availability. Each basin must have its own water supply and drainage so that each basin can be flooded, dried and cleaned according to its best schedule. Basins should never be in series, because in such a system, they cannot be dried and cleaned individually. Often the first basins are used as pre-sedimentation facilities.

Other techniques may also be identified with the surface spreading method: spate irrigation, check dams, underground dams and sand dams.

Spate irrigation is a well known traditional technique in the Near East consisting of watering terraced fields by diverting flood flows into them. Although the primary objective of spate irrigation is not aquifer recharge, this technique usually contributes significantly to increasing the infiltration of water into the underlying groundwater reservoirs. The storage of excess water into the aquifer and its subsequent retrieval alleviates some of the risks inherent to runoff based irrigation in arid zones.

Check dams are small structures built to slow down the velocity of water and induce flooding, allowing it to percolate into the alluvial aquifer. Floodwater is forced to expand over a large area, thus facilitating the infiltration of water.

Underground dams apply in shallow depth alluvial deposits to prevent groundwater from flowing away immediately after it is stored in the aquifer. They consist of digging a 1 to 1.5 m wide trench across the valley, down to the bedrock (which should be impervious) and then filling the trench either with loose impervious material (clay) or by building a wall made of local bricks. Underground dams may be complemented by **sand dams** consisting of raising the dam above ground by 1 or 2 metres so that the solid transport (usually sand and gravel) of the floods can accumulate behind the surface dam and thus increase the storage capacity of the alluvium.

Watershed management and water harvesting

Watershed management offers an effective method to intercept dispersed runoff. Many techniques of water conservation have been developed along hill slopes with the intention of preventing soil erosion and reducing surface runoff, then increasing the infiltration in the ground, thus recharging the aquifers. Traditional terraced agriculture is certainly one of the most common water harvesting methods in arid areas and particularly in the Near East. Where the terraces are well maintained, they effectively control runoff and improve aquifer recharge but, once allowed to fall into disuse, they progressively lead to gully erosion, collapse of the retaining walls, destruction of the whole system and severe modification of the hydrological regime. Therefore, whatever the economic virtues of such terraces, it should be recognized that their abandonment on a large scale can upset the hydrological conditions within a basin for a considerable period of time.

Because of the siltation problems in the surface reservoirs resulting from soil erosion in the upper catchment, large programs of soil and water conservation as well as forestation are being undertaken in several semi arid countries. Although the primary objective of the watershed management is to limit the soil erosion and therefore to reduce sediment accumulation in the surface reservoirs downstream, the effect of these practices may become significant on the aquifer recharge when large areas are included in the programs. However there are few examples of quantitative analysis of the modification of the water cycle in a catchment where soil and water conservation has been practiced.

Recharge wells

Artificial recharge by injection consists of using a conduit access, such as a tubewell, shaft or connector well, to convey the water to the aquifer. It is the only method for artificial recharge of confined aquifers or deep-seated aquifers with poorly permeable overburden. The recharge is instantaneous and there are no transit or evaporation losses. The method is very effective in the case of highly fractured hard rocks and karstic limestones.

Recharge wells or "injection" wells are similar in construction to pumped wells, using screened sections.

The great difficulty in using recharge wells is always their rapid clogging. While a basin may clog within years and in any case may easily be reconditioned, a recharge well may clog in a few days or weeks and is always difficult to keep in good operating condition. There are many possible causes of clogging.

- First there is suspended matter present in the water; it reduces the pore space in the gravel pack and in the formation at the interface with the gravel pack. This causes clogging to be more severe in aquifers with finer grain size.

- High content of organic matter may result in bacteriological growth. This is why clogging phenomena vary during the year as temperature of injected water changes.

• Clogging may also occur due to gas or air bubbles in the water, especially in shallow wells with low water pressure. It is essential to prevent underpressure in recharge pipes, valves and connections. This problem can be overcome by the use of small diameter recharge pipes in order to ensure the "pipe-full conditions

• Mixing of chemically dissimilar waters causes these waters to react and to form precipitates. Another form of clogging is caused by the swelling of clay particles which may be present in the target aquifer.

The most economical way to operate artificial recharge by injection consists of using dual purpose wells (injection and pumping) so that cleaning of the aquifer may be achieved during the pumping period. However, a pretreatment to eliminate the suspended matter is always necessary.

In addition to the water supply management measures described above, water demand management should be an essential element of any strategy to manage groundwater supplies, i.e. to maintain aquifer levels, or to increase and replenish groundwater supplies. Water demand management is the long-term ethic of saving water resources through the employment of water-saving technologies and activities. Using water efficiently will help ensure supplies for future generations. Across the country, our growing population is putting stress on available water supplies. Between 1950 and 2000, the U.S. population nearly doubled while the public demand for water more than tripled. Americans now use an average of 100 gallons of water each day—enough to fill 1,600 drinking glasses. This increased demand has put additional stress on water supplies and distribution systems, threatening both human health and the environment.

A recent government survey showed at least 36 states are anticipating local, regional, or statewide water shortages by 2013. But by using water more efficiently, we can help preserve water supplies for future generations, save money, and protect the environment.

Land Use Planning and its Effects on Groundwater

1. ***Describe where groundwater depletion is occurring in Louisiana, the areas at risk in the future. Evaluate the impact of groundwater depletion in watersheds.***

- The Sparta Aquifer is a confined aquifer that covers much of North Louisiana and Southern Arkansas. In Louisiana it is a narrow band through Natchitoches and Sabine parishes. The two areas are separated by a saltwater ridge below the Red River valley. Ground water movement is eastward toward the Mississippi River Valley and southward toward the Gulf of Mexico, except when altered by heavy pumping.

Recharge is from direct infiltration of rainfall in outcrop areas in the western part of the Sparta region from the Arkansas line in North Bossier Parish to Winn Parish, including Webster and Bienville Parishes, the movement of water through overlying terrace and alluvial deposits, and leakage from the Cockfield and Carrizo-Wilcox aquifers.

The Sparta is the primary source of water for many county, parish, municipal and industrial water systems. Because the Sparta provides clean cool water, it is an excellent source of water for many purposes.

"Cones of depression" have formed beneath major pumping centers (Monroe-West Monroe, Ruston, and Jonesboro-Hodge). Some wells may pump water at a slower rate or not at all if the water level is lower than the pump. In a heavily pumped area, naturally occurring salt water may be pulled into pumps. In some soils, excessive dewatering can lead to irreversible compaction, reducing the aquifer's ability to be recharged. Water levels are decreasing in some areas at approximately two feet per year.

In response to these critical water level declines, legislation was passed to create the Sparta Commission to address concerns of the aquifer. According to the creating statutes, the Sparta Commission's purpose is to study ways to put Sparta water "to the highest beneficial use" in terms of public welfare. The statutes note that "the continued uncontrolled use of groundwater from Sparta and other aquifers may create critical problems;" and they charge the Sparta Commission with studying "how to provide for the efficient administration, conservation, and orderly development of groundwater resources" in the Sparta area.

- The Chicot Aquifer is located in southwest Louisiana and is the most heavily pumped aquifer in the state. In the Lake Charles area, the Chicot is divided into the shallow alluvial sands, the "200-foot" sand, the "500-foot" sand, and the "700-foot" sand. East of Calcasieu parish the Chicot is divided into the "upper sand" (in hydraulic connection to the Atchafalaya sand, Abbeville sand, and "200-foot" sand) and the "lower sand" ("700-foot" sand). The "500-foot" sand is largely isolated except where it merges with the "700-foot" sand north of Calcasieu Parish. Fresh water in the Chicot and other southwestern Louisiana aquifers is separated from fresh water in southeast Louisiana by a saltwater ridge along the western edge of the Mississippi River valley. Salt water occurs within the Chicot along the coast and in isolated bodies north of the coast.

Recharge to the Chicot occurs primarily through the direct infiltration of rainfall in the interstream, upland outcrop-subcrop areas. Recharge also occurs by water movement from the Atchafalaya alluvium, downward infiltration through the clays south of the primary recharge outcrop area, upward movement from the underlying Evangeline aquifer, and inflow from the Vermilion and Calcasieu rivers. Water movement is generally toward the pumping centers at Lake Charles and Eunice. There is little movement of water from the west because of pumping in the Orange, Texas area.

Irrigation uses 68% of the water pumped from the Chicot and large withdrawals are also seen around the Lake Charles area for industrial purposes. It is also the source of drinking water for virtually every person living in southwest Louisiana.

The Chicot is declining at 1 – 2' per year and has averaged 0.8' per year since the 1900's. Although the aquifer produces a large amount of water, it has been determined to be a Sole Source Aquifer. Sole Source Aquifer designation indicates it is the only source of available groundwater for use in an area. There are no other viable sources of groundwater.

Attempts are being made for form a stakeholders group (similar to the Sparta Commission) to better manage this resource.

- The Southern Hills Aquifer System covers southeastern Louisiana (East Baton Rouge, St. Tammany, Tangipahoa, and Washington Parishes). It is the third most pumped aquifer in the state and pumping in the Baton Rouge area affects water levels in Tangipahoa Parish.

Recharge occurs primarily by the direct infiltration of rainfall in interstream, upland outcrop areas, and by the movement of water between aquifers. However, as this water moves downdip it is impeded by the Baton Rouge Fault.

The aquifer system is used predominately for public supply/drinking water and industrial purposes.

The water level declines range from 1-3' per year, with the 3' decline seen in Baton Rouge. This has caused a pronounced cone of depression in Baton Rouge which has affected the velocities and directions of groundwater flow and saltwater encroachment.

Capital Area Ground Water Conservation Commission was established in 1974 by Act 678 of the Louisiana Legislature. The Commission is a ground-water management district composed of five parishes in the Greater Baton Rouge area. These are the parishes of East and West Baton Rouge, East and West Feliciana, and Pointe Coupee. The Commission's functions are to promote the orderly development of the ground-water resources in the Capital Area District and to protect the quality of these resources. In response to research/studies the Commission has imposed restrictions on specific sands in the Southern Hills Aquifer, including restricting drilling, limiting pumping, and reserving specific sands for public supply only.

Carrizo-Wilcox Aquifer System, may see water level declines and production problems soon, if it not already. The Carrizo-Wilcox is the main source of drinking water in the lower Caddo and Bossier Parishes and DeSoto Parish. Data reported by the USGS indicates that the Carrizo – Wilcox aquifer system is a low yield aquifer system that generally produces water suitable for drinking water purposes which has been and is currently being used predominately for domestic and public water supply in mostly rural areas of Northwest Louisiana. However, water production from the aquifer system is reported to be physically restricted due to the aquifer's discontinuous nature and typically thin, lenticular and fine textured sand beds. This aquifer is being used for drilling operations for extraction of natural gas from the Haynesville Shale. The amount of water needed to drill and fracture a horizontal shale gas well generally ranges from 2 million to 4 million gallons, depending on the basin and formation characteristics. This could have serious impact on this low yield aquifer.

Decline in water levels in aquifers can impact watersheds due to the hydraulic connectivity between aquifers and streams. If a stream, under normal conditions, receives or loses water to an aquifer, the reduced water level will impact flow of the stream. This can disturb aquatic plants and animals, as well as sediments. Also declining water levels can cause soil compaction which can affect native plants and also retard or even stop recharge/percolation/infiltration. Subsidence is also a negative influence from declining water levels, which can change topography affecting drainage, stream bank stability, and sediment availability.

2. ***Design, propose and justify management practices to achieve water conservation and water use efficiency as part of a groundwater management plan in both an urban and rural/agricultural watershed. Identify strategies municipalities can take to protect and conserve groundwater.***

Groundwater management is the planned and coordinated monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of long-term sustainability of the resource.

In urban or city environments tools such as: education, reusing wastewater/gray water, harvesting rainwater, using sprinklers/drip irrigation can all be incorporated to reduce the amount of groundwater pumped/used. Education programs may be available through the LDEQ, LSU Cooperative Extension, or other community groups. Harvesting rainwater can be used for irrigation, filling pools, washing cars. Reusing treated wastewater with onsite home treatment or municipality treatment for flushing and application outdoors in landscaping, irrigation and washing vehicles. Gray water, untreated water from washing machine, showers (not toilets) can be used for subsurface irrigation of non-edible landscaping. Sprinklers and drip irrigation also conserve water in urban settings.

In Rural or agricultural areas some tools for conservation and efficiency are: Education, Aquifer Storage Reservoir (ASR), irrigation management, and tax incentives. Education is often available for farmers through the Master Farmer Program. ASR can be used to reduce seasonal fluctuation in aquifers by pumping groundwater into storage reservoirs during low demand time to be used during high demand time. Irrigation water management through proper use of grading, flood management to capture rainfall, and replacing flume ditches with underground pipe all contribute to conservation of groundwater. Encouraging use of alternate water source and tax incentives also are effective tools for conservation.

Municipalities can implement Drinking Water Protection Ordinances and/or watering schedules to protect drinking water sources. A drinking water ordinance, such as the model developed by the Louisiana Department of Environmental Quality, restricts/prohibits businesses that make or store chemicals or other substances that can potentially harm our drinking water from locating near a public supply well. A community may choose to enforce a watering schedule to restrict day and time of day a household may run water for washing cars and watering lawns. Both may be punished with fines or jail time.

3. ***Identify the advantages and disadvantages of instituting basin recharge programs and basin management programs to accommodate urban and agricultural overdraft challenges.***

Some advantages of developing a basin recharge/management program include: maintain water levels in aquifers, reducing seasonal over pumping, it is a good use for recycled water, land/lease owner is paid for use of the property. Disadvantages are: may be difficult to sustain long term, groundwater quality can suffer, cost, recharge area may be out of jurisdiction, and it requires cooperation from landowners.

Hydrology and Climatology (including Geohydrology)

Understand geohydrology basics such as the hydrologic cycle, types of aquifers, aquifer permeability, recharge and discharge, potentiometric surface, water table, and drawdown.

Nature recycles the earth's water supply through a process known as the water cycle or **hydrologic cycle**. This cycle operates continuously and receives energy from the sun. The major components of this cycle: evapotranspiration, condensation, precipitation/infiltration, percolation and runoff. This section explains key concepts and components of the hydrologic cycle.

Evapotranspiration is the combined net effect of two processes: evaporation and transpiration. Evapotranspiration uses a larger portion of precipitation than the other processes associated with the hydrologic cycle.

Evaporation is the process of returning moisture to the atmosphere. Water on any surface, especially the surfaces of mudholes, ponds, streams, rivers, lakes, and oceans, is warmed by the sun's heat until it reaches the point at which water turns into the vapor, or gaseous, form. The water vapor then rises into the atmosphere.

Transpiration is the process by which plants return moisture to the air. Plants take up water through their roots and then lose some of the water through pores in their leaves. As hot air passes over the surface of the leaves, the moisture absorbs the heat and evaporates into the air.

Condensation is the cooling of water vapor until it becomes a liquid. As the dew point is reached, water vapor forms tiny visible water droplets. When these droplets form in the sky and other atmospheric conditions are present, clouds will form. As the droplets collide, they merge and form larger droplets and eventually, precipitation will occur.

Precipitation is moisture that falls from the atmosphere as rain, snow, sleet, or hail. Precipitation varies in amount, intensity, and form by season and geographic location. These factors impact whether water will flow into streams or infiltrate into the ground. In most parts of the world, records are kept of snow and rainfall. This allows scientists to determine average rainfalls for a location as well as classify rainstorms based on duration, intensity and average return period. This information is crucial for crop management as well as the engineering design of water control structures and flood control.

Infiltration is the entry of water into the soil surface. Infiltration constitutes the sole source of water to sustain the growth of vegetation and it helps to sustain the ground water supply to wells, springs and streams. The rate of infiltration is influenced by the physical characteristics of the soil, soil cover (i.e. plants), water content of the soil, soil temperature and rainfall intensity. The terms infiltration and percolation are often used interchangeably.

Percolation is the downward movement of water through soil and rock. Percolation occurs beneath the root zone. Ground water percolates through the soil much as water fills a sponge, and moves from space to space along fractures in rock, through sand and gravel, or through channels in formations such as cavernous limestone. The terms infiltration and percolation are often used interchangeably.

Runoff is the movement of water, usually from precipitation, across the earth's surface towards stream channels, lakes, oceans, or depressions or lowpoints in the earth's surface. The characteristics that affect the rate of runoff include rainfall duration and intensity as well as the ground's slope, soil type and ground cover.

The hydrologic cycle consists of inflows, outflows, and storage. Inflows add water to the different parts of the hydrologic system, while outflows remove water. Storage is the retention of water by parts of the system. Because water movement is cyclical, an inflow for one part of the system is an outflow for another.

Looking at an aquifer as an example, percolation of water into the ground is an inflow to the aquifer. Discharge of ground water from the aquifer to a stream is an outflow (also an inflow for the stream). Over time, if inflows to the aquifer are greater than its outflows, the amount of water stored in the aquifer will increase. Conversely, if the inflows to the aquifer are less than the outflows, the amount of water stored decreases. Inflows and outflows can occur naturally or result from human activity.

Ground water is water held within the interconnected openings of saturated rock beneath the land surface. Water moves through the unsaturated zone into the saturated zone, where all the interconnected openings between rock particles are filled with water. It is within this saturated zone that the term "ground water" is correctly applied. Ground water is held in aquifers.

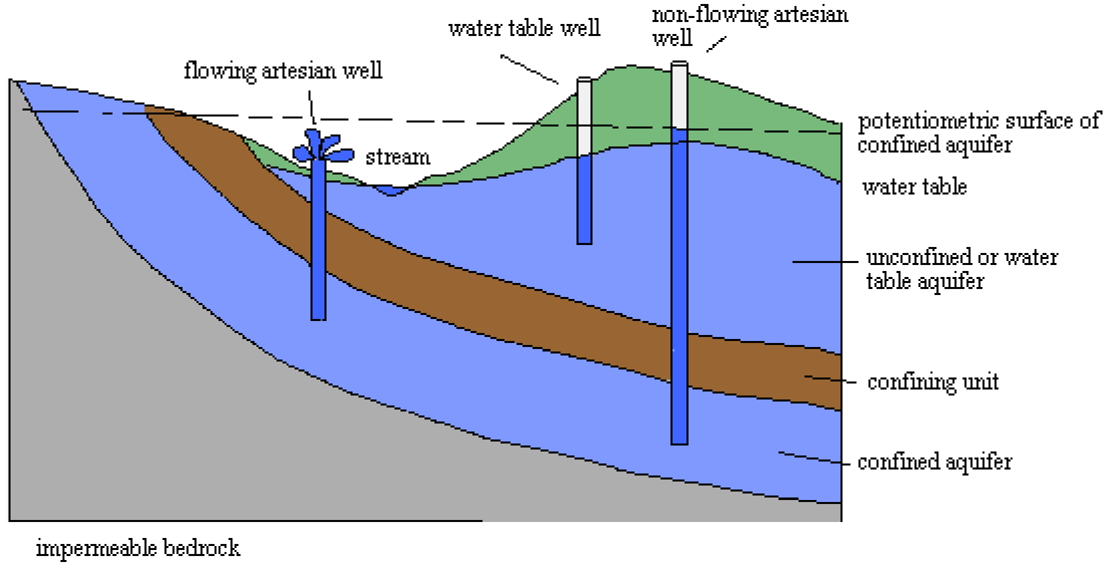
Aquifer is the term given to a rock unit that will yield water in usable quantities to wells or springs. An aquifer can be visualized as a giant underground sponge which holds water and which, under certain conditions, will allow water to move through it. Depending on the type, the aquifer may contain both the saturated and unsaturated zones or just the saturated zone.

The water-bearing rocks that compose aquifers consist either of unconsolidated (soil-like) deposits or consolidated rocks. Most consolidated rocks (otherwise known as bedrock) consist of rock and mineral particles of different sizes and shapes that have been welded together by heat and pressure or chemical reaction into a rock mass. Aquifers of this type are commonly composed of one or more of the following rocks: sandstone, limestone, granite, or lava. Water flows through these rocks through fractures, gas pores, and other openings in the rock.

Most unconsolidated materials consist of material derived from the disintegration of consolidated rocks. Unconsolidated deposits include, in different types of unconsolidated deposits, some or all of the following materials in varying combinations: soil-like materials, gravel, sand, silt, clay, and the fragments of shells of marine organisms. Sand dunes and gravel piles are examples of unconsolidated material. Water flows through these materials through the natural openings between particles. Louisiana aquifers are composed of unconsolidated deposits.

It is a common misconception that ground water is found in underground rivers, like those that form limestone caverns. In fact, ground water is more like the water in a sponge, held within the tiny pores of the surrounding aquifer material. Much like the flow of water in a river, however, the flow of ground water is subject to gravity and is almost always in motion, flowing from areas of higher elevation to areas of lower elevation. (In the case of ground water in confined aquifers, it is pressure rather than gravity that makes water move. In this case, water flows from areas of high pressure to areas of low pressure.) Just like what happens when a sponge soaked with water is tilted, gravity forces water to flow from one pore space or fracture to another. The steeper the gradient or slope, the faster the ground water will flow. It is important to note that the rate of ground water flow, especially in confined systems, is very slow compared to the flow of water on the surface. It is typically in the range of several inches per year to several feet per year.

For water to move freely through a rock, the pores and/or fractures must be large enough and connected enough so that the friction from the water moving past the rock particle does not impede the flow. The degree of an aquifer's porosity and permeability is key to the movement of ground water through an aquifer. **Porosity** is defined as the ratio of the volume of voids to the volume of aquifer material. It refers to the degree to which the aquifer material possesses pores or cavities which contain air or water. **Permeability** is the capacity of a porous rock, sediment, or soil to transmit ground water. It is a measure of the inter-connectedness of a material's pore spaces and the relative ease of fluid flow under unequal pressure.



In **unconfined aquifers** , the ground water only partially fills the aquifer and the upper surface of the ground water (the water table) is free to rise and decline. The ground water is at atmospheric pressure. The height of the water table will be the same as the water level in a well constructed in that unconfined aquifer. The water table typically mimics, in a subdued way, the topography of the land surface above, resulting in a water table with hills, valleys, or flat areas. It is important to note that unconfined aquifers, especially those close to the surface, can be vulnerable to contamination from activities on the land surface.

Confined aquifers may also be referred to as **artesian aquifers**. A confined aquifer is sandwiched between confining beds (layers of impermeable materials such as clay which impede the movement of water into and out of the aquifer). Because of the confining beds, ground water in these aquifers is under high pressure. Because of the high pressure, the water level in a well will rise to a level *higher than* the water level at the top of the aquifer. The water level in the well is referred to as the potentiometric surface or pressure surface.

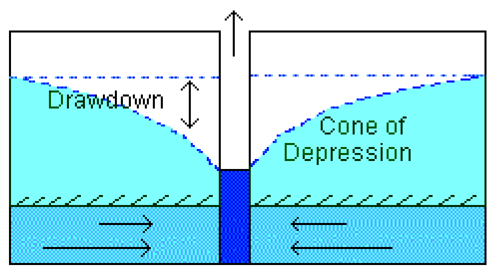
Even in a confined aquifer, water seeks its own level. Geological strata are not perfectly horizontal. At some point the lithological unit that comprises the confined aquifer is exposed to the surface. This is the aquifer's **recharge zone,** and it may be miles away from where one hopes to construct a well. The "confined" aquifer is actually unconfined at the recharge zone. In order for pressure to build, the water level in the recharge zone must be at a higher elevation than the base of the confining unit. When a well is drilled through the confining unit, usually far from the recharge zone, the water in this well will rise to the level of the water at the recharge zone. In some instances this may be above the surface of the ground, in which case the well is called a flowing artesian well. This same situation, where the level of the water at the recharge zone is above the base of the confining unit, leads to the appearance of springs or seeps where the confining unit is penetrated by a hillside. The movement of ground water to the surface into a spring, lake, river, or other surface water body; or outflow of ground water from a pumping or flowing well is known as **discharge**. Many rivers, lakes, and wetlands rely heavily on ground water discharge as a source of water. During times of low precipitation, these bodies of water would not contain any water at all if it were not for ground water discharge.

It is important to note that because of discharge, contaminants in ground water can flow into surface water bodies. This process can make the removal of contamination very complex.

It is important to note that confining beds not only serve to hamper the movement of water into and out of the aquifer, they also serve as a barrier to the flow of contaminants from overlying unconfined aquifers. For this same reason, however, contaminants that reach a confined aquifer through a poorly constructed well or through natural seepage, can be extremely difficult and expensive to remove.

Ground water is withdrawn from wells to provide water for everything from drinking water for the home and business, to water to irrigate crops, to industrial processing water. When water is pumped from the ground, the dynamics of ground water flow change in response to this withdrawal.

When a well is installed in an unconfined aquifer, water moves from the aquifer into the well through small holes or slits in the well casing or in some types of wells, through the open bottom of the well. The level of the water in the well is the same as the water level in the aquifer. Ground water continues to flow through and around the well in one direction in response to gravity.



When pumping begins, water begins to flow towards the well, in contrast to the natural direction of ground water movement. In response, the water level in the well falls below the water table, in the surrounding aquifer. As a result, water begins to move from the aquifer into the well. As pumping continues, the water level in the well continues to increase until the rate of flow into the well equals the rate of withdrawal from pumping. The movement of water from an aquifer into a well results in the formation of a cone of depression. The **cone of depression** describes a three dimensional inverted cone surrounding the well that represents the volume of water removed as a result of pumping. **Drawdown** is the vertical drop in the height between the water level in the well prior to pumping, and the water level in the well during pumping.

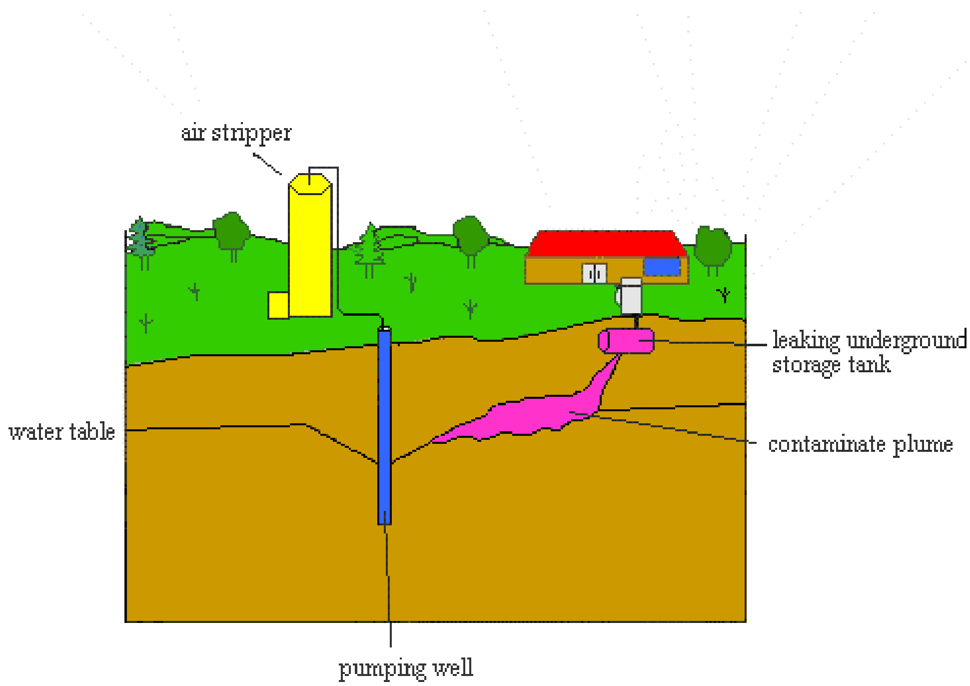
This information is used in a number of ways:

- knowledge of the drawdown helps to ensure a continuous supply of water; drawdown that reaches to the bottom of an aquifer could result in a "dry well"
- knowledge of the lateral, or sideways, extent of the cone of depression helps in identifying the overlying land area to be managed for ground water protection. A spill, for example, occurring in this area could percolate into the ground water and be "pulled in" by the pumping of the well
- pumping can result in a change of the ground water's source. For example, water that was once discharging into a stream may now be "pulled in" to the well. Surface water quality generally is more apt to be contaminated; in addition, the regulatory and monitoring standards for drinking water originating from surface water bodies are often

different than those originating from ground water sources.

The knowledge of natural ground water flow and the impact of pumping on flow is important in the strategic placement of wells (geographically and vertically) and the design of appropriate pumping rates and frequencies. This is important for a number of reasons:

- to ensure the specific source of water is known, be it a specific aquifer or a nearby surface water body,
- to pump out contaminated ground water so that it can be treated on the surface, such as by an air stripper. An air stripper remediates ground water contaminated by volatile organic compounds (VOCs). The illustration on the right shows water being treated using an air stripper.
- to manipulate local ground water flow so that contaminated ground water flows away from a drinking water source.



Identify and describe human impacts on the hydrologic cycle.

The earth's water supply remains constant, but man is capable of altering the cycle of that fixed supply. Population increases, rising living standards, and industrial and economic growth have placed greater demands on our natural environment. Our activities can create an imbalance in the hydrologic equation and can affect the quantity and quality of natural water resources available to current and future generations.

Water use by households, industries, and farms has increased. People demand clean water at reasonable costs, yet the amount of fresh water is limited and the easily accessible sources have been developed. As the population increases, so will our need to withdraw more water from rivers, lakes and aquifers, threatening local resources and future water supplies. A larger population will not only use more water but will discharge more wastewater. Domestic, agricultural, and industrial wastes, including the intensive use of pesticides, herbicides and fertilizers, often overload water supplies with hazardous chemicals and bacteria. Also, poor irrigation practices raise soil salinity and evaporation rates. These factors contribute to a reduction in the availability of potable water, putting even greater pressure on existing water resources.

Large cities and urban sprawl particularly affect local climate and hydrology. Urbanization is accompanied by accelerated drainage of water through road drains and city sewer systems, which even increases the magnitude of urban flood events. This alters the rates of infiltration, evaporation, and transpiration that would otherwise occur in a natural setting. The replenishing of ground water aquifers does not occur or occurs at a slower rate.

Together, these various effects determine the amount of water in the system and can result in extremely negative consequences for river watersheds, lake levels, aquifers, and the environment as a whole. Therefore, it is vital to learn about and protect our water resources.

Identify the major aquifers and aquifer systems in Louisiana.

- Carrizo-Wilcox Aquifer
- Sparta Aquifer
- Cockfield Aquifer
- Catahoula Aquifer
- Carnahan Bayou Aquifer
- Williamson Creek Aquifer
- Red River Aquifer

- North Louisiana Terrace Aquifer
- Mississippi River Alluvial Aquifer
- Evangeline Aquifer
- Chicot Aquifer
- Jasper Equivalent Aquifer System
- Chicot Equivalent Aquifer System
- Evangeline Equivalent Aquifer System

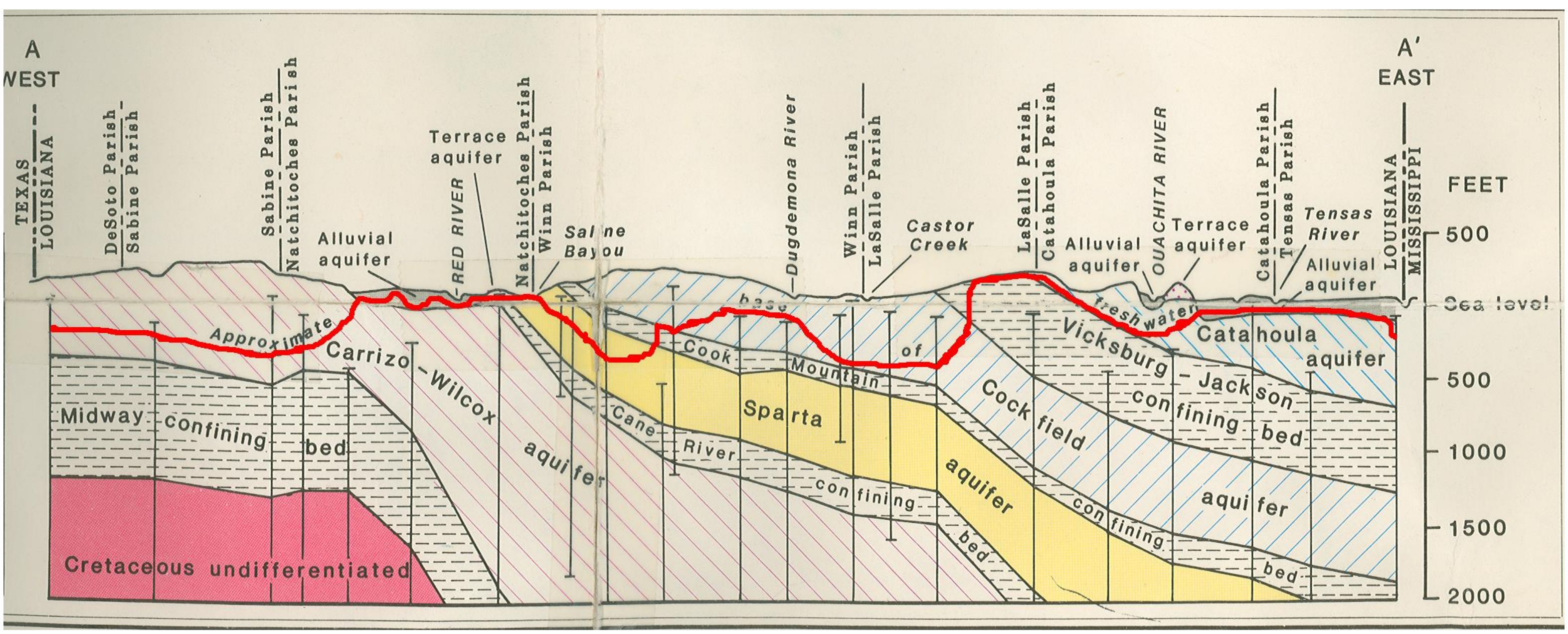
The Carnahan Bayou and Williamson Creek Aquifers are also collectively known as the **Jasper Aquifer System**. The Chicot Equivalent, Evangeline Equivalent, and Jasper Equivalent are also collectively known as the **Southern Hills Aquifer System**. The Chicot Equivalent Aquifer in southeast Louisiana is the same geologic age and has similar lithology to the Chicot Aquifer in southwest Louisiana. Likewise, the Evangeline Equivalent Aquifer is the same as the Evangeline

GEOHYDROLOGIC UNITS OF LOUISIANA

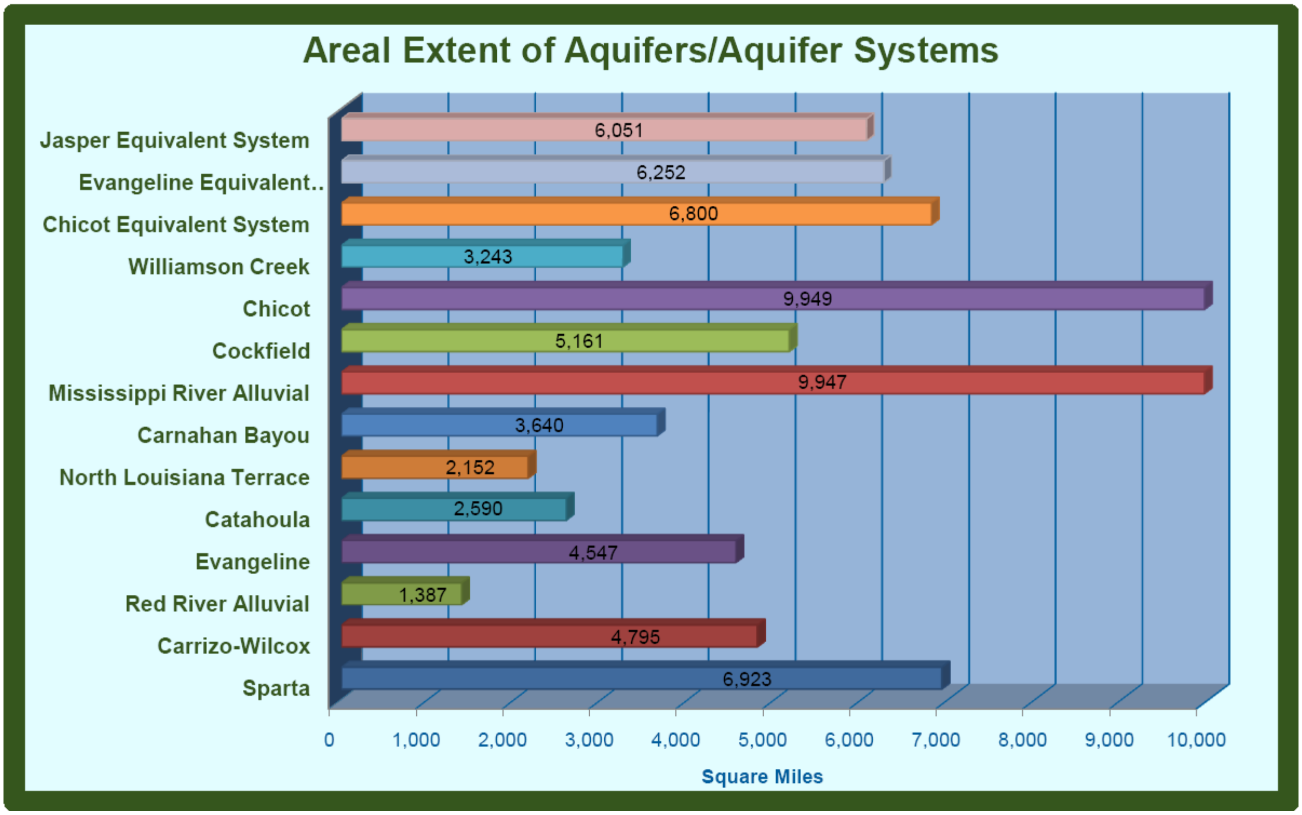
System	Series	Stratigraphic Unit	Hydrogeologic Unit								
			Northern Louisiana	Central Louisiana		Southwestern Louisiana		Southeastern Louisiana			
			aquifer or confining unit	aquifer system or confining unit		aquifer or confining unit		aquifer system or confining unit [1]	aquifer or confining unit [2]		
						Lake Charles area	rice growing area		Baton Rouge area	St. Tammany, Tangipahoa, and Washington Parishes	New Orleans area and lower Mississippi River Parishes [3]
Quaternary	Pleistocene	Red River alluvial deposits Mississippi River alluvial deposits Northern Louisiana terrace deposits Unnamed Pleistocene deposits	Red River alluvial aquifer or surficial confining unit Mississippi River alluvial aquifer or surficial confining unit Upland terrace aquifer or surficial confining unit	Alluvial aquifer, undifferentiated or surfical confining unit Prairie aquifer Montgomery aquifer Williana-Bentley aquifer	Chicot aquifer system or surficial confining unit	"200-foot" sand "500-foot" sand "700-foot" sand	Upper sand unit Lower sand unit	Chicot equivalent aquifer system or surficial confining unit	Mississippi River alluvial aquifer or surficial confining unit Shallow sand "400-foot" sand "600-foot" sand	Upland terrace aquifer Upper Pontchatoula aquifer	Gramercy aquifer Norco aquifer Gonzales-New Orleans aquifer "1,200-foot" sand
Tertiary	Pliocene	Fleming Formation: Blounts Creek Member	units absent	Evangeline aquifer or surficial confining unit				Evangeline equivalent aquifer system or surficial confining unit	"800-foot" sand "1,000-foot" sand "1,200-foot" sand "1,500-foot" sand "1,700-foot" sand	Lower Pontchatoula aquifer Big Branch aquifer Kentwood aquifer Abita aquifer Covington aquifer Slidell aquifer	
	? Miocene	Fleming Formation: Castor Creek Member		Castor Creek confining unit				unnamed confining unit			
		Fleming Formation: Williamson Creek Member Dough Hills Member Carnahan Bayou Member		Jasper aquifer system or surficial confining unit	Williamson Creek aquifer Dough Hills confining unit Carnahan Bayou aquifer			Jasper equivalent aquifer or surficial confining unit	"2,000-foot" sand "2,400-foot" sand "2,800-foot" sand	Tchefuncte aquifer Hammond aquifer Amite aquifer Ramsay aquifer Franklinton aquifer	
		Fleming Formation: Lena Member		Lena confining unit				unnamed confining unit			
	? Oligocene	Catahoula Formation		Catahoula aquifer				Catahoula equivalent aquifer system or surficial confining unit			
		Vicksburg Group, undifferentiated	Vicksburg-Jackson confining unit	no freshwater occurs in deeper units							
	Eocene	Jackson Group, undifferentiated									
		Claiborne Group: Cockfield Formation	Cockfield aquifer or surficial confining unit								
		Claiborne Group: Cook Mountain Formation	Cook Mountain aquifer or confining unit								
		Claiborne Group: Sparta sand	Sparta aquifer or surficial confining unit								
		Claiborne Group: Cane River Formation	Cane River aquifer or confing unit								
		Claiborne Group: Carrizo sand ?	Carrizo-Wilcox aquifer or surficial confining unit Wilcox aquifer								
	Paleocene	Wilcox Group, undifferentiated									
		Midway Group, undifferentiated	Midway confining unit								

[1] The interval containing the four aquifer systems is refered to as the Southern Hills aquifer system.
[2] Clay units separating aquifers in southeastern Louisiana are discontinuous, unnamed, and not listed herein.
[3] The interval containing the four aquifers is refered to as the New Orleans aquifer system.

Aquifer in central and southwest Louisiana, and the Jasper Equivalent Aquifer is the same as the Jasper Aquifer in central Louisiana. The youngest aquifers in the state are the alluvial and terrace aquifers. The oldest aquifers in the state are the Carrizo-Wilcox, Sparta, and Cockfield, respectively. They are located in north Louisiana. They contain saltwater in central and south Louisiana so they do not serve as fresh water aquifers for the rest of the state. They are relatively close to the earth’s surface in north Louisiana and get progressively deeper to the south. This is because the aquifers are not horizontal; they dip or “slope” in a south-easterly direction. Therefore an aquifer that “crops out” at the surface (recharge zone) in north Louisiana would be hundreds of feet below the surface near the Gulf of Mexico. This is illustrated in the diagram below, which is an east-west cross section of the aquifers in north central Louisiana. The red line represents the approximate base of fresh water.



The largest aquifer in the state is the Chicot aquifer; the smallest is the Red River Alluvial Aquifer (areal extent in square miles). The largest ground water withdrawal is from the Chicot Aquifer, which represents about 42% of the total ground water withdrawal in the state. The smallest withdrawal is from the Catahoula Aquifer. The areal extent of the aquifers and water use data can be found in the appendix.



Explain the hydrologic relationship and the environmental benefits of groundwater and surface water.

The hydrologic cycle describes the continuous movement of water above, on, and below the surface of the Earth. The water on the Earth's surface--surface water--occurs as streams, lakes, and wetlands, as well as bays and oceans. Surface water also includes the solid forms of water-- snow and ice. The water below the surface of the Earth primarily is ground water, but it also includes soil water.

The movement of ground water to the surface into a spring, lake, river, or other surface water body is known as discharge. Many rivers, lakes, and wetlands rely heavily on ground water discharge as a source of water. During times of low precipitation, these bodies of water would not contain any water at all if it were not for ground water discharge.

Surface water bodies may also recharge ground water. This occurs most often in arid areas. Lakes and dry creek beds may fill up with water during heavy rains. If the water table is low in underlying aquifers, water may seep from the sides of these water bodies and percolate into the ground water.

For ground water to discharge into a stream channel through the stream bed, the altitude of the water table in the vicinity of the stream must be higher than the altitude of the stream-water surface. This is known as a **gaining stream**. Conversely, for surface water to seep to ground water through the stream bed, the altitude of the water table in the vicinity of the stream must be lower than the altitude of the stream-water surface. This is known as a **losing stream**.

Ground-water chemistry and surface-water chemistry cannot be dealt with separately where surface and subsurface flow systems interact. The movement of water between ground water and surface water provides a major pathway for chemical transfer between terrestrial and aquatic systems. This transfer of chemicals affects the supply of carbon, oxygen, nutrients such as nitrogen and phosphorus, and other chemical constituents that enhance biogeochemical processes on both sides of the interface. This transfer can ultimately affect the biological and chemical characteristics of aquatic systems downstream.

It is important to note that because of the interaction of surface water and ground water, contaminants in ground water can flow into surface water bodies and vice-versa. This process can make the removal of contamination very complex.

How does global warming affect water supplies? Explain how this effect on water supplies impacts both groundwater and energy supplies.

Rising temperatures can lead to less snowpack, earlier and larger peak streamflows, potential reduction in total streamflows, greater evaporative losses, declining ecosystem health, sea level rise, more extreme weather events – including both floods and droughts, and hotter, drier summers. The water supply infrastructure was designed and engineered for timing and magnitudes of runoff based on our understanding of past hydrological conditions. Climate change and variability affects the timing, amounts, and form of precipitation, in turn, affecting all elements of water systems from watershed catchment areas to reservoirs, conveyance systems, and wastewater treatment plants. Altered supply and demand for water will require changes to how water systems are managed.

Climate change could affect ground-water sustainability in several ways, including (1) changes in ground-water recharge resulting from changes in average precipitation and temperature or in the seasonal distribution of precipitation, (2) more severe and longer lasting droughts which could lead to overdraft and salt-water intrusion, (3) possible increased demands for ground water as a backup source of water supply. Surficial aquifers, which supply much of the flow to streams, lakes, wetlands, and springs, are likely to be the part of the ground-water system most sensitive to climate change.

Water use accounts for a significant usage of electricity, natural gas, and fuel. The four principal elements of water system energy use are: (1) water extraction, conveyance, and storage; (2) water treatment and distribution; (3) end use (customer uses), including on-site water pumping, treatment, and thermal inputs (heating and cooling); and (4) wastewater collection, treatment, and discharge. Significant amounts of energy are required to extract water from its source and move it to where it will be treated and used. Additional energy is required to treat that water to meet standards. The amount of energy required for treatment depends on the source water quality; the more pollutants to be removed the more energy will be consumed. End use energy comprises a major portion of water-related energy use. Water users require energy to further treat water supplies (e.g., softeners and filters), circulate and pressurize water supplies (e.g., building circulation pumps), and heat and cool water for various purposes. Wastewater is collected and treated by a wastewater system and discharged (unless an on-site system is used), a process requiring energy. Wastewater is often pumped to treatment facilities where gravity flow is not possible (common in Louisiana) and standard treatments require energy for pumping, aeration, and other processes. The basic dynamic of global warming is that the earth's temperature is largely regulated by gases that trap heat in the earth's atmosphere. Increased concentrations of specific gases (known as "greenhouse gases) increase the heat-trapping ability of the atmosphere and are responsible for increasing temperatures. A significant percentage of greenhouse gases result from the burning of coal, oil and natural gas to produce energy. Increasing energy demands result is higher emissions of greenhouse gases. Water use efficiency and water recycling, along with ground water recharge and stormwater management, can provide significant opportunities to improve water supply reliability, cut costs, save energy, and reduce greenhouse emissions.

In addition, climate change can have an effect on energy production. Hydropower production is heavily influenced by variations in weather. Low snowpack or decreased precipitation diminishes hydropower generation and contributes to energy shortages. An overall increase in temperatures could lead to lower winter demand for heating and greater summer demand for air conditioning. Thus, when energy is needed in summer to meet the greater demand for air conditioning, hydropower's energy production will likely be hindered, given the predicted decrease in summer stream flows. Less water is available when demand is highest for both water supply and hydropower energy production. This is especially true in the western United States.

Appendix

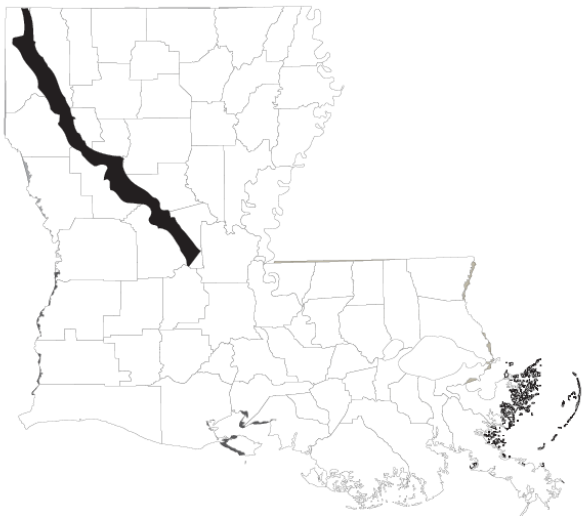
Areal Extent of Aquifers and Water Use

Taken from Water Use in Louisiana, 2005

DOTD/USGS Water Resources Special Report No. 16, 2007

RED RIVER

ALLUVIAL AQUIFER



Withdrawals by Parish

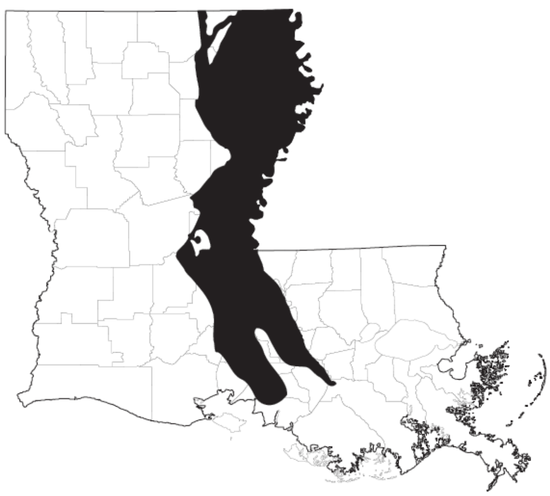
Parish	Mgal/d
Avoyelles	1.37
Bossier	.50
Caddo	1.97
Catahoula	.14
DeSoto	.04
Grant	.02
Natchitoches	2.65
Rapides	1.38
Red River	.57
Winn	.01

Withdrawals, in million gallons per day (Mgal/d)

Public supply	0.19
Industry	.00
Power generation	.00
Rural domestic	.24
Livestock	.47
Rice irrigation	2.64
General irrigation	2.44
Aquaculture	2.66
TOTAL	8.64

MISSISSIPPI RIVER

ALLUVIAL AQUIFER



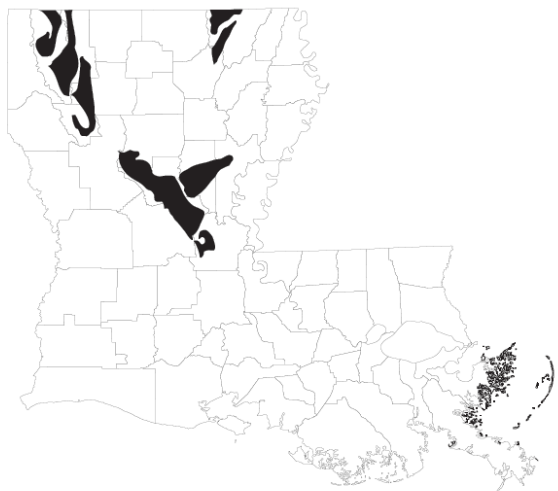
Withdrawals, in million gallons per day (Mgal/d)	
Public supply	9.51
Industry	33.93
Power generation	.49
Rural domestic	3.50
Livestock	.97
Rice irrigation	141.10
General irrigation	146.59
Aquaculture	65.89
TOTAL	402.00

Withdrawals by Parish

Parish	Mgal/d
Ascension	1.00
Assumption	10.77
Avoyelles	19.09
Caldwell	.04
Catahoula	18.00
Concordia	20.58
East Baton Rouge	.11
East Carroll	34.42
Franklin	46.12
Iberia	3.32
Iberville	22.54
Lafayette	.57
Lafourche	13.71
LaSalle	.01
Madison	18.95
Morehouse	83.43
Ouachita	.99
Pointe Coupee	11.08
Rapides	.07
Richland	24.75
St. James	3.34
St. Landry	16.17
St. Martin	5.90
St. Mary	.47
Tensas	14.98
Terrebonne	1.50
Union	.01
West Baton Rouge	6.90
West Carroll	23.19

UPLAND TERRACE AQUIFER

(NORTHERN LOUISIANA)



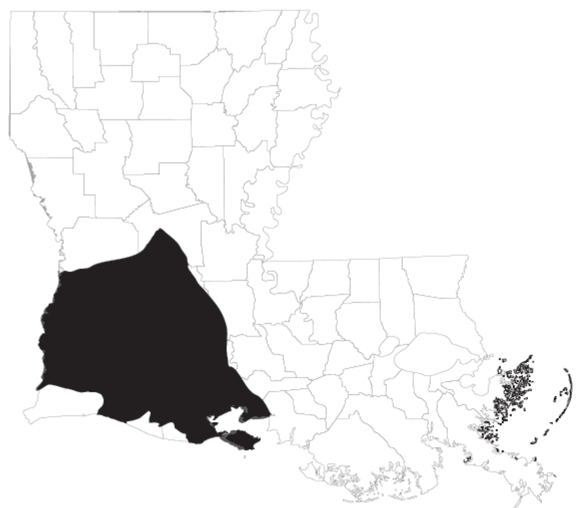
Withdrawals, in million gallons per day (Mgal/d)	
Public supply	6.34
Industry	.36
Power generation	.00
Rural domestic	.92
Livestock	.03
Rice irrigation	3.14
General irrigation	2.10
Aquaculture	.57
TOTAL	13.47

Withdrawals by Parish

Parish	Mgal/d
Avoyelles	0.63
Bienville	.03
Bossier	.98
Caddo	.47
DeSoto	.23
Grant	.63
LaSalle	1.22
Morehouse	5.92
Natchitoches	.12
Ouachita	.07
Rapides	2.11
Red River	.16
Sabine	.01
Union	.02
Vernon	.27
Webster	.36
West Carroll	.18
Winn	.03

CHICOT

AQUIFER SYSTEM



Withdrawals by Parish

Parish	Mgal/d
Acadia	168.47
Allen	23.23
Beauregard	12.35
Calcasieu	89.04
Cameron	6.02
Evangeline	68.62
Iberia	17.11
Jefferson Davis	151.78
Lafayette	43.13
Rapides	.76
St. Landry	31.63
St. Martin	5.91
St. Mary	2.79
Vermillion	40.38
Vernon	.42

Withdrawals, in million gallons per day (Mgal/d)

Public supply	93.49
Industry	58.43
Power generation	3.09
Rural domestic	12.63
Livestock	1.18
Rice irrigation	377.22
General irrigation	2.79
Aquaculture	112.81
TOTAL	661.64

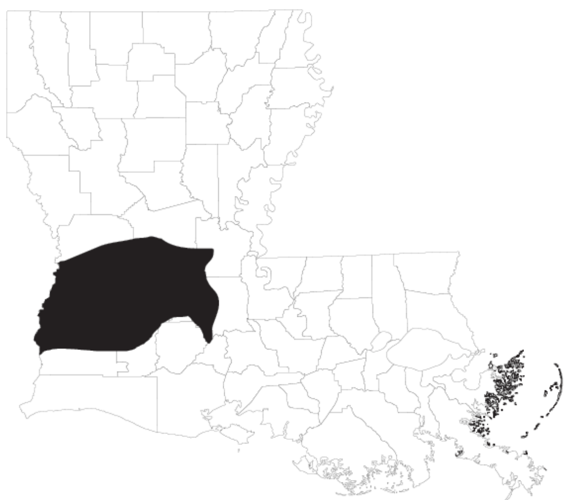
CHICOT EQUIVALENT AQUIFER SYSTEM (SOUTHEASTERN LOUISIANA)

Withdrawals, in million gallons per day (Mgal/d)	
Public supply	13.18
Industry	54.68
Power generation	3.41
Rural domestic	15.61
Livestock	.47
Rice irrigation	.00
General irrigation	1.37
Aquaculture	18.32
TOTAL	107.03

Withdrawals by Parish

Parish	Mgal/d
Ascension	10.65
Assumption	4.19
East Baton Rouge	25.28
East Feliciana	.21
Iberville	1.60
Jefferson	2.74
Livingston	3.31
Orleans	5.04
Plaquemines	.04
Pointe Coupee	1.87
St. Bernard	.03
St. Charles	4.89
St. Helena	.83
St. James	19.30
St. John the Baptist	9.63
St. Tammany	5.99
Tangipahoa	4.22
Washington	7.18
West Baton Rouge	.01
West Feliciana	.02

EVANGELINE AQUIFER

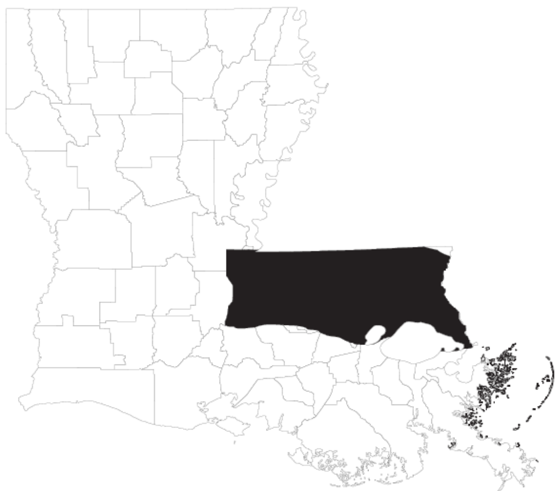


Withdrawals by Parish

Parish	Mgal/d
Allen	3.52
Avoyelles	2.48
Beauregard	3.19
Calcasieu	.77
Evangeline	4.15
Rapides	1.96
St. Landry	2.31
Vernon	.16

Withdrawals, in million gallons per day (Mgal/d)	
Public supply	13.94
Industry	2.98
Power generation	.00
Rural domestic	.27
Livestock	.09
Rice irrigation	.95
General irrigation	.18
Aquaculture	.12
TOTAL	18.53

EVANGELINE EQUIVALENT AQUIFER SYSTEM (SOUTHEASTERN LOUISIANA)



Withdrawals by Parish

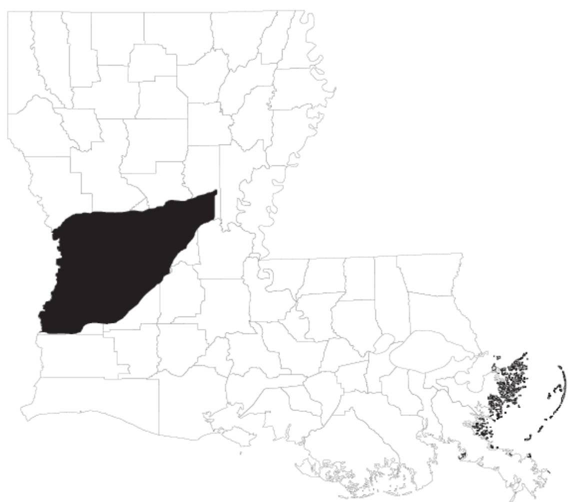
Parish	Mgal/d
East Baton Rouge	52.27
East Feliciana	0.37
Livingston	4.79
Pointe Coupee	3.17
St. John the Baptist	3.68
St. Tammany	12.32
Tangipahoa	2.64
Washington	0.25
West Baton Rouge	6.85
West Feliciana	0.76

Withdrawals, in million gallons per day (Mgal/d)

Public supply	59.21
Industry	20.56
Power generation	4.34
Rural domestic	2.36
Livestock	.33
Rice irrigation	.07
General irrigation	.15
Aquaculture	.07
TOTAL	87.09

JASPER

AQUIFER SYSTEM



Withdrawals by Parish

Parish	Mgal/d
Avoyelles	0.11
Beauregard	14.76
Concordia	1.65
Grant	.54
LaSalle	.03
Rapides	26.47
Sabine	.02
Vernon	5.42

Withdrawals, in million gallons per day (Mgal/d)

Public supply	31.74
Industry	15.40
Power generation	.12
Rural domestic	1.00
Livestock	.04
Rice irrigation	.20
General irrigation	.16
Aquaculture	.35
TOTAL	49.00

JASPER EQUIVALENT

AQUIFER SYSTEM

(SOUTHEASTERN LOUISIANA)

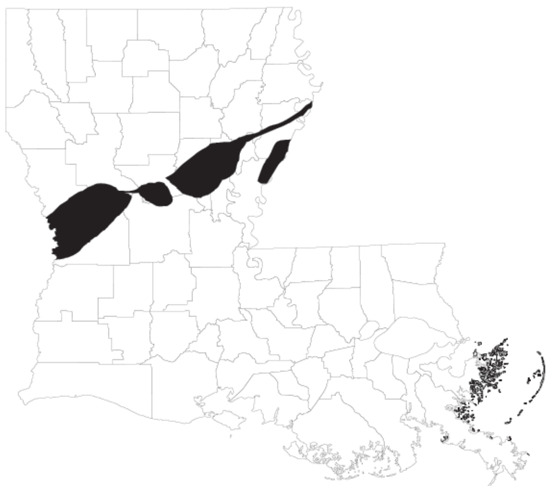
Withdrawals by Parish

Parish	Mgal/d
East Baton Rouge	68.24
East Feliciana	2.68
Iberville	1.25
Livingston	5.76
Pointe Coupee	4.57
St. Helena	.47
St. Tammany	4.39
Tangipahoa	12.21
Washington	21.53
West Baton Rouge	.01
West Feliciana	5.17

Withdrawals, in million gallons per day (Mgal/d)

Public supply	72.57
Industry	47.93
Power generation	5.20
Rural domestic	.31
Livestock	.12
Rice irrigation	.00
General irrigation	.03
Aquaculture	.14
TOTAL	126.29

CATAHOULA AQUIFER



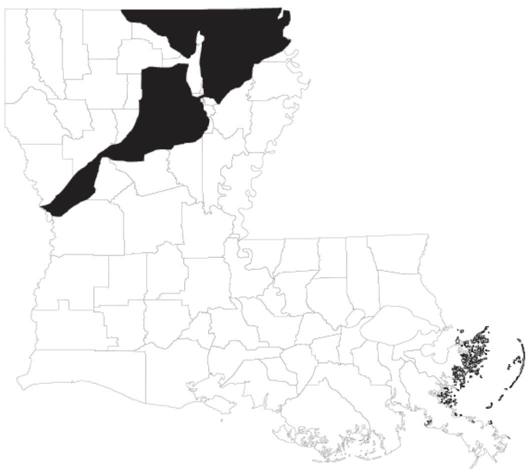
Withdrawals by Parish

Parish	Mgal/d
Catahoula	1.14
Concordia	.32
Grant	.47
LaSalle	.07
Natchitoches	.03
Rapides	.51
Sabine	.06
Vernon	.14

Withdrawals, in million gallons per day (Mgal/d)

Public supply	2.26
Industry	.07
Power generation	.00
Rural domestic	.24
Livestock	.03
Rice irrigation	.07
General irrigation	.09
TOTAL	2.75

COCKFIELD AQUIFER



Withdrawals by Parish

Parish	Mgal/d
Caldwell	1.97
Claiborne	.02
East Carroll	1.43
Grant	.20
Jackson	.08
LaSalle	.44
Lincoln	.04
Morehouse	.79
Natchitoches	.04
Ouachita	.14
Richland	1.39
Sabine	.10
Union	.25
Vernon	.04
West Carroll	1.47
Winn	.25

Withdrawals, in million gallons per day (Mgal/d)

Public supply	7.29
Industry	.00
Power generation	.00
Rural domestic	.54
Livestock	.02
Rice irrigation	.36
General irrigation	.29
Aquaculture	.17
TOTAL	8.66

SPARTA AQUIFER

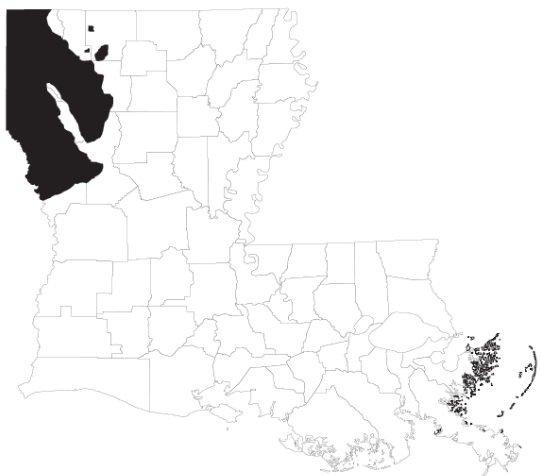
Withdrawals by Parish

Parish	Mgal/d
Bienville	12.09
Bossier	.19
Caddo	.04
Caldwell	.05
Claiborne	2.53
Jackson	1.95
LaSalle	.20
Lincoln	7.76
Morehouse	4.44
Natchitoches	.50
Ouachita	22.32
Sabine	.17
Union	5.20
Webster	7.44
Winn	3.08

Withdrawals, in million gallons per day (Mgal/d)

Public supply	35.70
Industry	30.01
Power generation	.00
Rural domestic	1.44
Livestock	.15
Rice irrigation	.18
General irrigation	.30
Aquaculture	.19
TOTAL	67.98

CARRIZO-WILCOX AQUIFER



Withdrawals by Parish

Parish	Mgal/d
Bienville	1.01
Bossier	2.46
Caddo	5.22
DeSoto	3.25
Natchitoches	1.23
Red River	.99
Sabine	1.87
Webster	1.53

Withdrawals, in million gallons per day (Mgal/d)

Public supply	7.49
Industry	2.29
Power generation	.00
Rural domestic	4.60
Livestock	.28
Rice irrigation	.42
General irrigation	1.59
Aquaculture	.88
TOTAL	17.56

WATER/ENERGY NEXUS

1. ***Assess the negative energy impact that is associated with desalination and explain why this is a major concern.***

Desalination is “energy intensive” in that salt is removed from water by forcing water through a series of membranes and filters. The cost is high, but needs to be compared to alternatives which may include transporting water miles and miles by some method such as a pipeline. When desalination becomes a factor, it usually means that there is a water shortage affecting the population.

2A. ***Evaluate the impact of energy production on fresh water supplies.***

See the “Energy-Water Nexus Overview” which describes the Energy-Water Connection and is an excellent summary document (http://www.sandia.gov/energy-water/nexus_overview.htm).

2B. ***Compare and contrast the effects of nuclear and fossil fuel plants.***

Nuclear power plants need more cooling water than fossil fired power plants. This is because the steam in nuclear plants is designed to operate at lower temperatures and pressures, which means they are less efficient at using heat from the reactor and thus require more water for cooling.

Some nuclear power stations use large quantities of water, but most of this water is returned to the source and can be used again by other consumers. Depending on the cooling technology utilized, the water requirements for a nuclear power station can vary between 20 to 83 percent relative to other nuclear stations.

One of the sources of water for nuclear power stations and fossil fuel plants could be saline aquifers where water is more plentiful than in fresh water aquifers. Industry prefers to use fresh water since the treatment of saline water escalates costs.

2C***. Effect of increased usage of electric cars on groundwater.***

Electric cars that plug into an electricity source for recharging could sharply increase water consumption in the United States. From one study, the calculated usage, consumption, and withdrawal during petroleum refining and electricity generation in the U.S. showed that each mile driven with electricity consumes about three times more water (0.32 vs. 0.07-0.14 gallons per mile) than gasoline. Increase in water usage presents a significant potential impact on regional water resources and should be considered when planning for a plugged-in automotive economy.

2D***. In the framework of evaluating the impact of energy production on fresh water supplies, compare and contrast the production of biofuels to the refining of fuels from fossil fuel sources.***

According to the National Groundwater Association and the US Geological Survey, the US withdraws a total of 365 billion gallons of fresh water each day. The US ethanol industry at this time uses 76 million gallons per day, or less than one-tenth of one percent of the total daily use in the US and less than one percent of the total daily industrial use of water.

Significant quantities of water-primarily for process and cooling are needed to refine petroleum products into fuel. Refineries use about 1 to 2.5 gallon of water for every gallon of product, meaning that the US, which refines 800 million gallons of petroleum products per day, consumes about 1 to 2 billion gallons of water each day to produce fuel (USDOE, 2006).

*3A.****Outline a management policy that will protect and manage groundwater resources for human, environmental, economic needs, and energy production.***

Evaluate a state's groundwater resources including current and projected demands on the aquifers of the state. Develop a water use conservation program. Study alternatives to groundwater use such as surface water to include treatment and transmission system and reclaimed water. Provide incentives for conservation. Explore the use of alternative technologies. Develop education and conservation programs. Develop a well registration process and evaluate the effect of new wells upon existing wells. Develop a drought program and who will be priority users of the groundwater. Evaluate the sustainability of aquifers and focus on withdrawal rates from stressed aquifers. Have a contingency plan for emergencies. Develop rules and regulations as needed to achieve the management policy. These are elements of Louisiana's ground water management intentions developed by the Louisiana Department of Natural Resources. The department also has authority regarding energy production and is currently monitoring aquifer sustainability (use of groundwater for formation hydraulic fracturing) with regard to the Haynesville shale gas play in North Louisiana from the standpoint of economic needs and energy production. See 3B for an environmental discussion.

3B. ***Differentiate the different roles that government agencies will have in protecting and managing groundwater resources as well as how water use is regulated at the state/province and federal level.***

At the state level the Louisiana Department of Environmental Quality is responsible for protecting ground water quality through its Drinking Water Protection Program, its ambient groundwater monitoring program, and its RECAP program which assures that groundwater that has become contaminated is remediated to a proper standard.

At the state level the Department of Natural Resources, Office of Conservation, is responsible for groundwater management where water quantity issues arise. See 3A above.

At the federal level the US Environmental Protection Agency develops rules and regulations as well as guidance regarding water quality. The states develop rules and regulations at least as stringent as the federal and follow federal guidance to a great extent. Many programs to implement desired federal goals are administered by the states and funded by the federal government. The United States Geological Survey is a professional organization that uses technology to identify and help resolve water quality and quantity issues. Their publications aid states in their work.